Wall Assembly R-Value

R-Value Table

Material	R/ Inch	R/ Thickness
Insulation Materials		
Fiberglass Batt	3.14	
Fiberglass Blown (attic)	2.20	
Fiberglass Blown (wall)	3.20	
Rock Wool Batt	3.14	
Rock Wool Blown (attic)	3.10	
Rock Wool Blown (wall)	3.03	
Cellulose Blown (attic)	3.13	
Cellulose Blown (wall)	3.70	
Vermiculite	2.13	
Autoclaved Aerated Concrete	3.90	
Urea Terpolymer Foam	4.48	
Rigid Fiberglass (> 4lb/ft3)	4.00	
Expanded Polystyrene (beadboard)	4.00	
Extruded Polystyrene	5.00	
Polyurethane (foamed-in-place)	6.25	
Polyisocyanurate (foil-faced)	7.20	
Construction Materials		
Concrete Block 4"		0.80
Concrete Block 8"		1.11
Concrete Block 12"		1.28
Brick 4" common		0.80
Brick 4" face		0.44
Poured Concrete	0.08	
Soft Wood Lumber	1.25	
2" nominal (1 1/2")		1.88
2x4 (3 1/2")		4.38
2x6 (5 1/2")		6.88
Cedar Logs and Lumber	1.33	
Sheathing Materials		
Plywood	1.25	
1/4"		0.31
3/8"		0.47
1/2"		0.63
5/8"		0.77

3/4"		0.94
Fiberboard	2.64	
1/2"		1.32
25/32"		2.06
Fiberglass (3/4")		3.00
(1")		4.00
(1 1/2")		6.00
Extruded Polystyrene (3/4")		3.75
(1")		5.00
(1 1/2")		7.50
Foil-faced Polyisocyanurate (3/4")		5.40
(1")		7.20
(1 1/2")		10.80
Siding Materials		
Hardboard (1/2")		0.34
Plywood (5/8")		0.77
(3/4")		0.93
Wood Bevel Lapped		0.80
Aluminum, Steel, Vinyl (hollow backed)		0.61
(w/ 1/2" Insulating board)		1.80
Brick 4"		0.44
Interior Finish Materials		
Gypsum Board (drywall 1/2")		0.45
(5/8")		0.56
Paneling (3/8")		0.47
Flooring Materials		
Plywood	1.25	
(3/4")		0.93
Particle Board (underlayment)	1.31	
(5/8")		0.82
Hardwood Flooring	0.91	
(3/4")		0.68
Tile, Linoleum		0.05
Carpet (fibrous pad)		2.08
(rubber pad)		1.23
Roofing Materials		
Asphalt Shingles		0.44
Wood Shingles		0.97
Windows		
Single Glass		0.91

w/storm		2.00
Double insulating glass (3/16") air space		1.61
(1/4" air space)		1.69
(1/2" air space)		2.04
(3/4" air space)		2.38
(1/2" w/ Low-E 0.20)		3.13
(w/ suspended film)		2.77
(w/ 2 suspended films)		3.85
(w/ suspended film and low-E)		4.05
Triple insulating glass (1/4" air spaces)		2.56
(1/2" air spaces)		3.23
Addition for tight fitting drapes or shades, or closed blinds		0.29
Doors		
Wood Hollow Core Flush (1 3/4")		2.17
Solid Core Flush (1 3/4")		3.03
Solid Core Flush (2 1/4")		3.70
Panel Door w/ 7/16" Panels (1 3/4")		1.85
Storm Door (wood 50% glass)		1.25
(metal)		1.00
Metal Insulating (2" w/ urethane)		15.00
Air Films		
Interior Ceiling		0.61
Interior Wall		0.68
Exterior		0.17
Air Spaces		
1/2" to 4" approximately		1.00

Example of Wall Section:

Component	R-value
Wall - Outside Air Film	0.17
Siding - Wood Bevel	0.80
Plywood Sheathing - 1/2"	0.63
3 1/2" Fiberglass Batt	11.00
1/2" Drywall	0.45
Inside Air Film	0.68
Total Wall Assembly R-Value	**13.73**

*Source: http://www.coloradoenergy.org/procorner/stuff/r-values.htm

Lightweight concrete acts as insulation

Suitable as fill for floors, roof decks, and other applications

Lightweight concrete weighs substantially less than concrete made with gravel or crushed stone aggregates. Generally the term is applied to concrete weighing 120 pounds per cubic foot or less—and weights can range on down to 12 or 15 pounds per cubic foot. Such concretes are often used as thermal and sound insulation even though their compressive strengths may sometimes be as low as 5 psi.

At the upper end of the lightweight concrete spectrum—120 pounds per cubic foot—we have materials which have full structural competence as well as a measure of insulation (more about these concretes will be found in Reference 1). Here we describe the lighter weight concretes—50 pounds per cubic foot or less—which are the most effective as insulation. These can be used in combination with other materials in wall, roof, and floor systems where they are most advantageous in reducing heating and cooling costs.

TABLE 1. ESTIMATED R-VALUE (THERMAL RESISTANCE) FOR INSULATING LIGHTWEIGHT CONCRETES, NORMALLY DRY CONDITION, COMPARED WITH STRUCTURAL CONCRETES

Unit weight pounds per cubic foot	Thickness of concrete, inches			
	1	2	4	6
20	1.43	2.86	5.72	8.58
30	1.00	2.00	4.00	6.00
40	0.83	1.66	3.32	4.98
50	0.67	1.34	2.68	4.02
60	0.52	1.04	2.08	3.12
Structural lightweight, 110 pcf	0.19	0.38	0.76	1.13
Normal weight concrete at 145 pcf	0.075	0.15	0.30	0.45

NOTE: These are typical or representative values. Individual products may have greater insulating effectiveness. Based on information given in the PCA publication, *Concrete Energy Conservation Guidelines*.

How insulating concretes are made

The lightest of the lightweight concretes may be divided into two groups according to their composition:

- *Cellular concretes*—made by incorporating air voids in a cement paste or cement-sand mortar, through use of either preformed of formed-in-place foam. These concretes weigh 15 pounds per cubic foot or more.
- *Aggregate concretes*—made with expanded perlite or vermiculite aggregate or expanded polystyrene pellets. Oven-dry weight ranges from 15 to 60 pounds per cubic foot.

When normal weight sand is included in these mixes, increased weight and strength usually can be achieved, but the concretes weighing 50 pounds per cubic foot and less are the most effective for thermal insulation.

Concrete properties to be considered

Within the range of available lightweight concretes, the lightest ones generally offer the best insulating properties, but little strength. The user must consider not only the insulating value of the concrete but how it will be combined with other construction materials.

Thermal conductivity—Insulating materials are now commonly compared in terms of R-values, which offer an indication of the resistance to flow of heat. The higher the R-value, the better the insulation. Some estimated values for concretes of different densities are given in Table 1. These are typical or representative values only, and each concrete mix design must be evaluated if precise values are needed. Remember that moisture in concrete can affect the insulating capability just as it does other insulating materials. The R-value goes down when the concrete gets wet.

Compressive strength—Compressive strength generally increases with increasing unit weight (see Table 2). Strength level required de-

TABLE 2. ESTIMATED COMPRESSIVE STRENGTH OF SOME INSULATING LIGHTWEIGHT CONCRETES

Concrete type	Dry unit weight, pcf pounds	Comressive strength, psi
Perlite	20-40	80-450
Vermiculite	15-40	70-500
Cellular, with sand	25-35	130-250
Cellular, no sand	15-40	70-450

Based on values presented in the report of ACI Committee 523, published in the *ACI Manual of Concrete Practice*, Part 5.

pends on the use of the concrete. A compressive strength of 100 psi or less may be acceptable for insulating underground steam lines. However, roof and floor fill requires enough early strength to withstand the traffic of workmen. Strengths of 100 to 200 psi are usually adequate, although up to 500 psi is sometimes specified.

Drying shrinkage—Shrinkage is not usually critical for low density fill or insulating concretes, although excessive shrinkage can cause curling. Moist-cured cellular concretes made without aggregates do have high shrinkage.

Resistance to freezing and thawing—Lightweight insulating concrete is usually protected and not exposed directly to the elements. As for normal weight concretes, resistance to damage by freezing and thawing depends on the entrained air content of the mix.

Perlite concrete

Perlite is a type of lava mined in large open pits in the Western United States, then crushed to sand sized particles, and expanded by heating.

Perlite insulating concrete is a mixture of expanded perlite, portland cement, water and an air-entraining agent. The dry concrete weighs from 20 to 50 pounds per cubic foot, depending on the mix selected. Perlite concrete can be placed monolithically on flat, uneven, curved, or sloping surfaces. On flat roofs, the thickness of perlite concrete can be varied to provide specified drainage slopes.

The designer selects the strength and insulating value that he considers most appropriate to his project. The physical properties of perlite concrete are controlled by its dry density which is the principal factor in its specification. An ideal balance among reduced dead load, adequate compression and indentation strengths, and good insulating value can be achieved with a density of 24 to 28 pounds per cubic foot. For insulated floor slabs on grade, a density of 20 to 24 pounds per cubic foot is frequently recommended.

Vermiculite concrete

Vermiculite is a soft, laminated, mica-like mineral that has few uses in its natural state but when heated and flaked becomes a lightweight aggregate of great value for fill and insulating concrete. The expanded product weighs from 6 to 10 pounds per cubic foot.

Vermiculite insulating concrete is made of expanded vermiculite aggregate, air-entraining admixture, portland cement, and water, all mixed and applied according to precise procedures. The ratio of cement to aggregate determines the density, strength, and insulating value of the finished concrete. As used in the average roof deck, the ratio ranges from 1:4 to 1:8 by volume.

The resulting concrete mixture is usually pumped to the roof site and screeded into place over the structural base. Vermiculite concrete is installed in thicknesses of 2 inches or more, depending on design needs and strength requirements. It weighs from 20 to 40 pounds per cubic foot, with compressive strengths from 90 to 500 psi.

Expanded polystyrene bead concrete

Expanded polystyrene processed to a nominal density of 1 pound per cubic foot, can be used as aggregate in lightweight insulating concrete. Typically, polystyrene bead lightweight insulating concrete consists of Type I or Type II portland cement, polystyrene aggregate, air entraining agent and water. Sometimes additional mix components such as sand, limestone, or pozzolans may be used.

Insulating roof fill of polystyrene bead concrete usually has a dry density of 26 to 30 pounds per cubic foot. Densities are available from 25 to 60 pounds per cubic foot. Fire resistance has been verified by small scale fire tests conducted by the Portland Cement Association.

Polystyrene beads are not readily wetted by water, and cement paste or mortar does not adhere very well to them. Furthermore, their extremely low density makes them tend to segregate by floating out of the mix. To overcome this, the manufacturers have developed a number of bond-improving admixtures. Epoxy resin or an aqueous dispersion of polyvinyl propionate have been recommended.

Shrinkage and swelling strains are high compared to dense concretes, and allowance must be made for this in the design. Polystyrene bead concrete has good workability, is quite pumpable, and requires minimum vibration in placement.

Cellular concrete

Cellular insulating lightweight concrete has a multitude of macroscopic, discrete air cells uniformly distributed throughout the mix. These cells may account for up to 80 percent of the total volume. The concrete may weigh from 12 to 90 pounds per cubic foot. Density and strength can be controlled to meet specific design requirements by varying the amount of air.

Proprietary methods and agents used to produce cellular concrete can be considered in two groups: those using a preformed foam and those using formed-in-place foam. Formed-in-place foam is generated by special high speed mixing of water, foaming agent, cement, and aggregates (if any) to allow foam to form in the mixer. Initially large air bubbles are reduced to a reasonably uniform size as mixing proceeds.

By the other method, a uniform preformed aqueous foam is blended with a portland cement and water slurry using only enough water to assure proper hydration of the cement and to make placing easier. The foam is made by blending a foam concentrate, water and compressed air in predetermined proportions in a foam generator calibrated for discharge rate.

As with other lightweight insulating concrete, the strength and thermal conductivity depend on density. The material can be made so light that it barely holds its shape during handling. R-values may be as high as 2 per inch of thickness for a density of 20 pounds per cubic foot, or as low as 0.43 for 90-pounds-per-cubic-foot density.

Cellular concrete is totally incombustible (8 inches of concrete represents a fire rating of about 8 hours); yet it can be worked much like wood. It has been widely used for floor and roof fills. Recently highway departments have begun to use it as a stabilized fill.

References

1. ACI Committee 523, "Guide for Cellular Concretes Above 50 pcf, and for Aggregate Concretes Above 50 pcf with Compressive Strengths Less Than 2500 psi, (ACI 523.3R-75)," American Concrete Institute, Box 19150, Detroit, Michigan 48219. This report was published in the February 1975 issue of the Journal of the American Concrete Institute, pages 51-65, and is reprinted in Part 5 of the ACI Manual of Concrete Practice.

2. "Lightweight Insulating Concrete for Floors and Roof Decks," CONCRETE CONSTRUCTION, July 1978, 5 pages beginning on page 411.

3. "Low Density Concretes for Insulation and Fill," CONCRETE CONSTRUCTION, March 1981, 3 pages beginning on page 253.

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Architect's Technical Reference

Materials / Systems >> Thermal & Moisture Protection

R-values of Insulation and Other Building Materials

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) provides R-values of building materials in their 1997 *Handbook of Fundamentals*.

R-values are additive. For instance if you have a material with an R-value of 12 and another material with an R-value of 3, then both materials combined have an R-value of 15.

Many energy modeling programs and code calculations require U-values of assemblies. The U-value is simply the reciprocal of the total R-value of the assembly.

$$U = \frac{1}{R_1 + R_2 + R_3 \text{ etc}}$$

Building Material R-Values

MATERIAL	THICKNESS	R-VALUE
Air Films		
Exterior		0.17
Interior Wall		0.68
Interior Ceiling		0.61
Air Space		
Minimum 1/2" up to 4"		1.00
Building Board		
Gypsum Wall Board	1/2"	0.45
Gypsum Wall Board	5/8"	0.5625
Plywood	1/2"	0.62
Plywood	1"	1.25
Fiber board sheathing	1/2"	1.32
Medium Density Particle Board	1/2"	0.53
Insulating Materials		
R-11 Mineral Fiber with 2x4 metal studs @ 16" OC		5.50
R-11 Mineral Fiber with 2x4 wood studs @ 16" OC		12.44
R-11 Mineral Fiber with 2x4 metal studs @ 24" OC		6.60
R-19 Mineral Fiber with 2x6 metal studs @ 16" OC		7.10
R-19 Mineral Fiber with 2x6 metal studs @ 24" OC		8.55
R-19 Mineral Fiber with 2x6 wood studs @ 24" OC		19.11
Expanded Polystyrene (Extruded)	1"	5.00
Polyurethane Foam (Foamed on site)	1"	6.25
Polyisocyanurate (Foil Faced)	1"	7.20
Masonry and Concrete		
Common Brick	4"	0.80
Face Brick	4"	0.44
Concrete Masonry Unit (CMU)	4"	0.80
Concrete Masonry Unit (CMU)	8"	1.11
Concrete Masonry Unit (CMU)	12"	1.28
Concrete 60 pounds per cubic foot	1"	0.52
Concrete 70 pounds per cubic foot	1"	0.42
Concrete 80 pounds per cubic foot	1"	0.33

Concrete 90 pounds per cubic foot	1"	0.26
Concrete 100 pounds per cubic foot	1"	0.21
Concrete 120 pounds per cubic foot	1"	0.13
Concrete 150 pounds per cubic foot	1"	0.07
Granite	1"	0.05
Sandstone / Limestone	1"	0.08
Siding		
Aluminum / Vinyl (not insulated)		0.61
Aluminum / Vinyl (1/2" insulation)		1.80
Flooring		
Hardwood	3/4"	0.68
Tile		0.05
Carpet with fiber pad		2.08
Carpet with rubber pad		1.23
Roofing		
Asphalt Shingles		0.44
Wood Shingles		0.97
Glazing		
Single Pane	1/4"	0.91
Double Pane with 1/4" air space		1.69
Double Pane with 1/2" air space		2.04
Double Pane with 3/4" air space		2.38
Triple Pane with 1/4" air spaces		2.56
Triple Pane with 1/2" air spaces		3.23
Doors		
Wood, solid core	1 3/4"	2.17
Insulated metal door	2"	15.00

The R-values above for specific assemblies like doors and glazing are generalizations because they can vary significantly based on special materials that the manufacturer uses. For instance, using argon gas in a double pane insulating glass unit will dramatically improve the R-value. Consult manufacturer literature for values specific to your project.

The values in the table above were taken from a number of sources including: The ASHRAE Handbook, ColoradoENERGY.org, and Building Construction Illustrated by Francis D.K. Ching. Other minor sources were also used. Archtoolbox does not test materials or assemblies.

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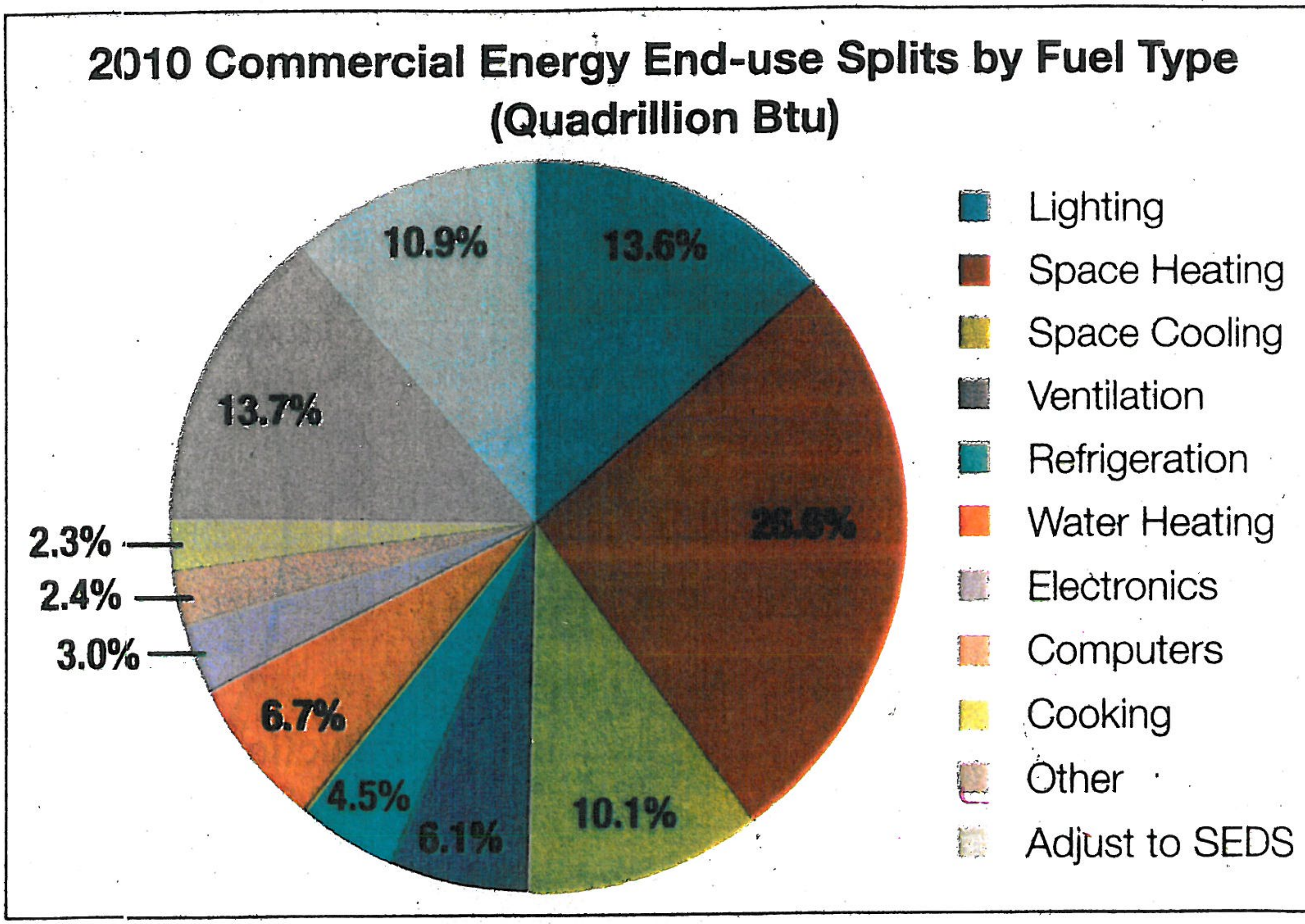

The U.S. Department of Energy's (DOE's) *Buildings Energy Data Book* monitors commercial sector energy consumption.

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